Camano Island State Park Tidal Marsh Reconnection Feasibility Study

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Introduction

Camano Island State Park is a 244-acre park with 6,700 ft of shoreline along Saratoga Passage on the western side of Camano Island. The purpose of this feasibility study is to evaluate the potential for creating a pocket estuary in the park where there is a mix of salt marsh and freshwater marsh. There is some evidence that a historic pocket estuary existed at this location and pocket estuaries have been identified as important rearing habitat for ESA-listed Chinook. The waterway adjacent to Camano Island State Park has been identified as a migration corridor for juvenile Chinook, and a new pocket estuary at this location could provide an important habitat type that has been reduced and degraded throughout the Puget Sound.

Skagit River System Cooperative (SRSC) is partnering with Washington State Parks to assess the feasibility of restoring natural hydrologic processes to a historic tidal marsh within the park. SRSC completed a preliminary analysis of the restoration potential for a pocket estuary at this site in 2010. SRSC has contracted Blue Coast Engineering PS, Inc (Blue Coast) to provide an evaluation of the optimal configuration of a new tidal channel that will be sustainable, fit within the existing land use constraints, and require minimal maintenance. This study is a continuation of previous work completed by Skagit River System Cooperative (SRSC) and Pacific Northwest National Laboratories (PNNL). Two different conceptual restoration designs were evaluated. Results and discussion are presented in this report and indicate that a pocket estuary at this location may require significant infrastructure to maintain park features and the tidal channel opening would require maintenance to stay open.

This report documents the evaluation of the relevant coastal processes and sediment transport to evaluate the feasibility of maintaining an open channel for a pocket estuary at Camano Island State Park. A brief description of existing conditions at the site is provided below, followed by evaluation of four design alternatives and a recommendation for a preferred alternative. The preferred alternative was developed into a preliminary design by SRSC.

Existing Physical Conditions

Blue Coast understands that the proposed restoration of a tidal marsh at Camano Island State Park is based in part on areas in similar geomorphic contexts which have or previous had tidal marshes (McBride and Beamer, 2010). Historic t-sheets did delineate this area as a marsh, but not an embayment and historic aerial photos may show remnants of a marsh. The park has extensive infrastructure including access road, parking, boat ramp, two restroom facilities, and a picnic shelter (Figure 1). In addition, there is a freshwater perennial stream which enters the park at the south end and flows into a freshwater wetland on the east side of the access road through the park.

Geology and Geomorphology

The Camano Island State Park shoreline is located within a drift cell that originates at the southeast boundary of the park (CGS, 2017 [Figure 1]). The dominant direction of drift (sediment transport) is to the north along the west facing shoreline of the park. To the east of the park, regional drift cell mapping indicates sediment is transported away from the park, from west to east (Figure 1). While the net drift used in drift cell mapping is an indication of the larger length scale processes that can occur over decades, the geomorphic landform classifications discussed below, indicate more localized geology and sediment transport patterns.

Geomorphic landform classifications were established within shoreline parcels and the mapped shoreline types indicate the dominant process within that parcel (CGS, 2017 [Figure 1]). Within the southern parcel of the park property, the area is mapped as an accretion shoreform. This designation indicates the interaction of the coastal processes and geology in this area have developed a barrier beach which typically accretes sediment and tends to build seaward over time (Figure 2). Historically, there may have been a barrier embayment (pocket estuary) which encompassed the majority of the surface area behind the accretion shoreform (McBride and Beamer, 2010). There is no direct evidence of the existence of a pocket estuary at this location as it is not mapped as such in historic maps, but it is in a similar position geomorphically to other pocket estuaries and elevations behind the berm indicate that much of the area would be wet daily at mean higher high water (MHHW).

During a site visit in July 2017, there was evidence of saltwater over washing the barrier beach and pushing sediment and logs into the marsh adjacent to the picnic shelter. In addition, vegetation behind the barrier beach is dominated by more salt tolerant plants than fresh water plants based on visual observations on site. Flooding of the marsh to the south of the picnic shelter was observed during a second site visit in November 2017 after a storm event.

The shoreline to the north of the park and to the southeast of the park are mapped as feeder bluffs. Feeder bluffs erode as a result of precipitation, slope failures, and wind-waves and provide a source of sediment to the beaches that are down drift (in the direction of drift or transport) from the feeder bluffs. At Camano Island State Park, the sediment from the feeder bluffs to the southeast of the park boundary are discharging sediment (Figure 2) which is then transported alongshore to the west and north. According to the drift cell map, the net transport at the base of these feeder bluffs diverges and some of the sediment moves southwest (towards the park) and some moves northeast (away from the park). Wind-waves are the primary driver of alongshore sediment transport which will be discussed further in the next section.

The barrier beach at the site is a mixed sand and gravel beach. Soils are loose silty sand in the top 1 foot and mixed sand and gravel 1 to 2.5 ft below grade (MTC 2011). Sediment samples were analyzed as part of the early feasibility study and showed the median grain size was 5 millimeters (mm [McBride and Beamer 2010]). Surface sediment materials are finer at the north end of the park and coarsen around the point at the south end of the park (Figure 3). Beach slopes range from 0.1 to 0.15 at the project site. Along the highest elevation of the barrier beach driftwood has accumulated and some vegetation has established.

A geotechnical investigation was conducted by Aspect Consulting with the primary goal determine if a historic lagoon was present at the site (Anderson and Otto 2018). The study involved the exploration of 3 boreholes. Historic salt marsh geology would present as fine-grained clay or sand deposits with significant organic material present. Based on site exploration and geologic mapping of the area, geologic material at the site was largely native beach deposits and re-working of beach deposits for use as on-site fill, and glaciomarine deposited during the Everson Interstade of the Fraser glaciation. The opinion of this study was that no historic marsh was present at the site (Anderson and Otto 2018).

Water Levels

Water level information was established and mapped using elevation contours relative to mean lower low water (MLLW) from LIDAR at the project site (Figure 4). Water level datums were established based on tidal datums provided by National Oceanic Atmospheric Administration (NOAA) at Greenbank, WA (station #9447883) which is on the opposite side of Saratoga Passage as Camano Island State Park.

NOAA collects water level data at a station in Seattle (tide gage #9447130 from 1976 to present) and it is the longest record of water levels in Puget Sound. The recorded data in Seattle is used to predict water elevations in Greenbank and establish tidal datums. Water level data recorded between 1983 and 2011 were analyzed by NOAA to determine the annual exceedance probability levels of 99%, 50%, 10% and 1%. The tidal datums and extremal water levels for the project site are shown in Table 1.

Tidal datums are still water levels and wind-waves can result in wave run-up of at 1 to 2 feet above these water levels depending on wind speeds and wave heights. The 1-year through 100-year extreme water levels (Table 1) include increases in water levels from meteorological effects and storm surge. Low pressure weather systems can raise overall water levels temporarily, commonly referred to as storm surge. For every 1 millibar decrease in atmospheric pressure a corresponding 1 cm rise in sea level can be expected (VanArendonk, 2017).

Road access to the beach at Camano Island State Park comes down at the southern end of the property and follows the toe of the hillside to the parking area at the north end of the property, near the boat ramp (Figure 1). Based on still water level mapping the access road at the current elevation would become inundated at MHHW if tidal flow was restored to the state park. In addition, the restrooms and picnic shelters would be surrounded by flooding into the low marsh areas within the park and become islands during MHHW and potentially at 1-year return interval flooding. Approximately 5 acres of park area can be seasonally inundated at MHHW based on existing LiDAR elevation.

Table 1. Water levels

Water Level	Relative to MLLW		Relative to NAVD88	
	(m)	(ft)	(m)	(ft)
100 year (1%)	4.46	14.5	3.74	12.2
10 year (10%)	4.17	13.6	3.45	11.3
1 year (99%)	3.93	12.8	2.74	10.5
Mean Higher High Water (MHHW)	3.5	11.3	2.74	8.9
Mean High Water (MHW)	3.2	10.4	2.47	8.1
Mean Tide Level (MTL)	2.0	6.6	1.3	4.2
Mean Sea Level (MSL)	2.0	6.6	1.3	4.2
Mean Low Water (MLW)	0.8	2.7	0.1	0.4
Mean Lower Low Water (MLLW)	0	0	-0.7	-2.3

Wind-waves

Wind-waves are developed by wind blowing across open water (fetch). In Puget Sound winds are topographically steered by the complex landforms and this limits wind-wave growth based on the distance along the primary direction of local wind. Wind data collected at Cama Beach State Park (Finlayson 2006), approximately 2 miles north of the project site, were previously analyzed and plotted in a wind rose diagram (ESA 2017 [Figure 5]). The winds recorded at Cama Beach show the most frequently occurring winds blow from the north and the south to the south-southeast (146° to 168°). The strongest winds blow from the south and south-southeast at speeds exceeding 30 miles per hour (mph).

Wind waves were also measured at Cama Beach State Park between September 2002 and May 2005 (Finlayson 2006). The peak wind events generated wind-waves with a wave height of 1 to 1.5 ft and wave periods of 2 to 3 seconds. Cama Beach is in close proximity to Camano Island State Park, along the same waterway, and has a similar fetch. Therefore, wind-waves measured at Cama Beach State Park are assumed to be representative of wind-waves at Camano Island State Park.

The effect of wind-waves on the shorelines will be observed through wave set-up and wave run-up on the beach slope. Wave set-up and run-up represent the vertical component of wind-waves on the beach slope above the still water level. Combined wave set-up and wave run-up were calculated according to the theories presented by Komar (1998) for reflective beaches based on deep-water wave height, water depth of wave breaking, and beach slope. The largest winds as measured at Cama Beach across the largest fetch will result in wave run-up of approximately 1 ft above the still water level. At this site, storm surge would result in water levels of 12.5 ft MLLW which is similar to the elevation of the 1-year extreme water level. Site observations indicate that wave run-up and set-up during a moderate storm event in November 2017 exceeded the elevation of the barrier beach (13 to 14 ft MLLW) which is equivalent to a 10-year extreme water level.

While the largest wind-waves during high water levels are responsible for coastal flooding, wind-waves which mobilize the largest volumes of sediment tend to occur during intervals of mean tide water elevations because they break on the beach face. The ability for wind-generated waves to mobilize sediment which can then be transported is determined by a combination of the wind-wave height, wave period, water depth and grain size distribution of the sediment. The friction calculated as shear stress generated under wind-waves needs to be sufficiently large to mobilize the sediment of the mixed sand and gravel beaches at the project site and initiate transport. In addition, the volume of material transported is dependent on the duration of the wind event, the angle of the waves on the beach, and the beach slope. Sediment transport under wind-waves at Camano Island State Park is discussed in detail in the next section of this report.

Sediment Transport

The median grain size at the project site was estimated to be 5 mm during the previous study (McBride and Beamer 2010). However, this sediment sample was taken near the boat ramp and is finer than the sediment on the southern end of the park (Figure 3). Field observations indicated there is a very coarse gravel armor layer at most if not all locations within the park that must be mobilized before significant alongshore transport can occur. During a long-term sediment transport study in Puget Sound, gravel transport was directly measured and compared to predicted gravel transport (Finlayson, 2006). A grain size diameter of 20 mm produced the most accurate predictions of sediment movement under measured forces. At the project site, 20 mm represents the D_{85} from the sediment sampled near the boat ramp.

Cross- and long-shore transport at the site were estimated using information collected at Cama Beach (Finlayson, 2006). Cross-shore transport resulted in a swash bar formation equal in height to 1.5 x breaking wave height at an elevation just above the highest water level during an event. This could result in a swash bar of 0.5 to 2 feet in height depending on the storm event. The bars or berms which form during storm events are typically redistributed during the next storm event and therefore contribute to alongshore transport. At other sites in Puget Sound this type of transport has been observed as gravel mounds propagating alongshore which erode gravel from one location and deposit it in the direction of drift on the middle to upper beach. In this manner, transport under wind-waves can result in a localized increase or decrease in beach elevation of 0.5 to 1 ft.

Bed shear stress under wind-waves have been calculated based on a combination of methods from Soulsby (2006) and Soulsby and Campbell (2005). These formulas were applied for the range of wind-waves at the project site, the range of water levels using a sediment grain size of 20 mm to describe wind-waves which can act on the beach at Camano Island State Park throughout a tidal cycle. Below is a summary of the results of the analysis of bed shear stress under wind-waves:

- Critical bed shear stress for a 20 mm size grain is 17.8 Pascals (Pa).
- Wind-waves at the project site (1 to 1.5 ft) in water depths of 6 feet or deeper do no generate enough shear stress to mobilize sediment and typically do not affect sediments on the low tide terrace.
- A 1-foot wind-wave breaking on the beach can mobilize the full range of sediment grain sizes at the site and will primarily affect the middle to upper beach.

The bed shear stress analysis indicates that most of the sediment transport occurs between the elevations of the beach at mean tide level and mean higher high water, which is consistent with other studies of sediment transport in Puget Sound (Finlayson 2006; Côté and Osborne 2013).

Sediment which can be mobilized by wind-waves is then transported alongshore. The general equation for longshore transport by Van Rijn (2013) was used to calculate longshore transport as a function of the sediment grain size, beach slope, wave height and wave angle. Longshore transport rates were calculated over a 24-hour interval for the range of grain size distributions and wave conditions at the Camano Island State Park. Wind-waves generated by 20 mph wind from the south can generate longshore transport of approximately 100 to 350 cubic feet (4 to 13 cubic yards) per day. Based on the wind data for Camano Island, a wind-wave event which will generate a measurable change in beach elevation will occur approximately 5 or 6 days a year at the project site.

This is consistent with information provided by Washington State Parks who have reported sediment accumulation on the boat ramp frequently in the winter. Sediment is cleared from the boat ramp and placed on the down drift side (to the north) to be re-entrained into the nearshore.

Existing Conditions Summary

There is no direct evidence of a former barrier embayment or primary tidal channel at Camano Island State Park. However, the geomorphology and elevations suggest a barrier embayment could be supported by the surrounding conditions. A geotechnical investigation was conducted at the site, and although only 3 boreholes were evaluated, none provided soil or sediment evidence of a historic marsh.

The park has extensive infrastructure including access road, parking, boat ramp, two restroom facilities, and picnic pavilion. These resources need to be maintained. Ideally, the freshwater perennial stream which enters the park at the south end and flows into a freshwater wetland on the east side of the access road would be connected to a restored salt marsh at the site.

The shoreline at Camano Island State Park can be described as high energy as compared to other Puget Sound shorelines. Sediment which is eroded from the feeder bluffs to the east is sorted in the cross-shore and transported in the alongshore by wind-waves leaving a coarse gravel beach on the south end of the park and finer mixed sand and gravel beach on the north side of the park. The shoreline is accreting sediment evidenced by the accumulation of sediment on the boat launch each year.

Evaluation of Preliminary Marsh Restoration Design

SRSC has proposed to develop a saltwater marsh at Camano Island State Park by creating an open tidal channel which would allow tidal flooding of some portion of the park. Tidal channels within barrier embayments is generally maintained by current velocity produced by the rising and falling of water levels from tides combined with surface water inflow. These flows produce the force on the bottom and sides of the channel (shear stress) to mobilize and transport sediment which has been deposited within the channel as a result of longshore drift from wind-waves. Several studies have parameterized tidal channels and estuaries to determine what processes control and which parameters can be used to predict the geometry of stable inlet channels. It is important to note that many of these studies have been conducted on sand dominated coasts where the current velocities or hydrodynamic energy required to move the sediment is significantly less than on mixed sand and gravel beaches.

While there are many region-specific controls on the stability of tidal channels, some generalizations about the hydrodynamics of stable inlet systems based on existing literature can be made:

- The force exerted by the current velocity through the inlet must exceed the threshold required to mobilize the average sediment grain size (D_{50}) within the system on a regular basis to keep the channel open.
- Natural tidal channels tend to move laterally over time (and not always in the same direction) either in response to longshore drift or simply to a path of lower resistance to avoid deposited sediment and debris.
- The surface water input to the estuary (a function of watershed area and precipitation) has an effect on the areal extent of marsh within a system.

- The wind-wave energy and sediment supply have a significant effect on the growth of the barrier spit and the potential for closure of the system.
- Stable inlets typically have cross-sectional depth averaged velocities of at least 3 fps.

Work from an active study on the design guidelines for barrier embayment restoration in Puget Sound being funded by WDFW under an ESRP learning grant (Côté et al 2018) hereafter referred to as the ESRP Barrier Embayment Project was used in developing the design criteria for this project. In addition, studies of pocket estuaries in the Whidbey Basin by SRSC which are being incorporated into the ESRP Barrier Embayment Project were utilized (Beamer 2019).

Findings from the ESRP Barrier Embayment Project specific to Puget Sound and Whidbey Basin indicate:

- Intertidal volume of the estuary is the best predictor of sustainable tidal inlet cross-sectional area and cross-sectional width.
- The tidal channel outlet depth is also correlated to intertidal volume, but not as strongly as the cross-sectional area or width as the depth appears to be influenced by other factors such as dominant habitat type (Marsh, Mud flat, or Lagoon).
- Sediment availability and habitat type (lagoon, marsh, or mud flat) are significant factors in the determination of tidal channel geometry but need more refined parameters to include in regression models.

These principles and information were utilized to develop conceptual design options for the tidal marsh at Camano Island State Park.

Barrier Embayment Channel Configuration

This study identified a few other barrier embayments in Puget Sound that are or would have been similar to Camano Island to evaluate potential tidal channel configurations for the site.

- KVI Beach is on the east side of Vashon Island with wind-waves from the north and south (Figure 6). The site has a similar topography to Camano Island and has a channel flowing to the south out of the embayment.
- Onamak is on Camano Island, north of both Camano Island State Park and Cama Beach State Park (Figure 7). It has similar topography and wind-waves to the site and appears to have had a historic channel flowing to the south that was closed or filled based on the t-sheet.
- Devil's Head is in south sound, at the very southern end of the Key Peninsula (Figures 8 and 9). It has a southerly fetch of 5 miles and eroding bluffs to the east, with net sediment drift from the south to north. The existing channel is on the southside of the middle of the site.

Two of the three sites evaluated with similar geomorphology and wind-wave exposure had channels draining the embayments to the south. Another factor driving channel design is where sediment has historically accumulated. Based on a 1956 aerial photo of the site is appears that sediment accumulates in greater volume on the north end of the site (Figure 10). In addition, there is some evidence of barrier embayments with northerly flowing channels in the Whidbey Basin becoming closed due to sediment accumulation over time.

The original concept for tidal marsh reconnection at the site proposed a channel to the north of the site (McBride and Beamer, 2010 [Figure 11]). Historic t-sheets indicate a historic outlet from a marsh in the middle of the park, but no channel connection to Puget Sound is indicated on these charts. A benefit of this original concept design is that it is away from the existing road and through the middle of the park which is already at a low elevation. However, this design may interfere with the existing boat launch if the channel moves north over time. This design would require major infrastructure changes at the park and increase the risk of flooding at the northern parking lot.

Tidal circulation modelling was conducted using this original concept to determine the potential tidal currents to provide flushing of sediment. The numerical modelling showed typical tidal currents are 0.7 feet per second (fps) peak velocity and produce negligible shear stress. The largest velocities and bed shear stress only occur 1% of the time and are not sufficient to mobilize the largest sediment sizes at the project site. In addition, the numerical modelling of the site may have underpredicted the potential for flooding of the northern parking area through delineation of the boundary conditions (Figure 12).

Sediment transport under wind-waves at the project site will likely make it difficult for a new tidal channel to be self-sustaining without maintenance. To evaluate this further two channel configurations have been considered for four conceptual design alternatives.

Tidal Marsh Design Alternatives

Four new conceptual design alternatives were developed and include configurations with a tidal channel to the north and south of the site (Figures 13 through 16). The advantages (benefits) and disadvantages of each of the four alternatives are listed in Table 2. All of the concepts will require some extent of protective berms to maintain existing park benefits therefore this is not listed as an advantage or disadvantage.

The first alternative (Figure 13), similar to the original concept has a tidal channel to the north of the site, but proposes to outlet the channel north of the existing boat launch. There are a number of benefits to this design alternative. Grain size distribution of the sediment in the north of the site indicates a lower energy regime with less annual transport and therefore less likelihood of the tidal channel filling with sediment. The boat launch would act as a groin and maintenance on the ramp could support maintenance of the spit seaward of the channel and parking lot. This configuration would likely reduce the potential for natural wood accumulation within the tidal channel. Access to the channel for maintenance could be done when boat ramp maintenance is completed to reduce costs.

Potential negatives for this design alternative are that northern facing channels in the Whidbey Basin tend to become filled with sediment and potentially close off after time. This channel configuration may lead to scour at the base of the bluff. The turn around and parking area would likely lose space in this configuration and require additional fill to prevent frequent flooding. The access road would need to be elevated, including a bridge over the stream crossing. Two pedestrian bridges would also be required. The perennial marsh would still be disconnected from tidal influence in this alternative.

The other three alternatives evaluated a channel to the south with varying degrees of inundation of the park. All three of these alternatives take advantage of the low-lying marsh on the south side of the park which already experiences regular flooding from storm surge overwash of the barrier beach. The narrowest portion of the barrier beach is on the south side of the park indicating this is a transport zone and accumulation rates are lower so material can move across the beach and not deposit on the beach or in the new tidal channel. A channel on the south side of the park is away from major infrastructure, such as the boat launch, parking, turnaround, and smaller restroom so the channel can be wider and allow for natural channel adjustment. A channel on the south end of the park might be able to connect perennial stream to the new salt marsh. The three alternatives for the south tidal channel are summarized as follows:

A. Alternative 2A (Figure 14) provides a minimal tidal marsh (approximately 2.5 acres) which is confined by a protective berm to the south of the picnic shelter. This option would not require any additional infrastructure changes, but provides the smallest net ecological benefit. In addition, tidal currents will be lowest because of smallest tidal prism which will present challenges for maintaining an open tidal channel.

B. Alternative 2B (Figure 15) provides a larger tidal marsh (approximately 4.4 acres) and flushing of the marsh on the east side of the road. This option can combine the changes to the road with a protective berm to reduce the potential for flooding of the road. While this option provides a larger net ecological benefit, the tidal currents may still be reduced as compared to Alternative 1 or 2c.

C. Alternative 2C (Figure 16) maximizes the ecological benefits while decreasing the changes to the park infrastructure as compared to Alternative 1. The marsh area for this alternative is approximately 8 acres. The existing perennial marsh is closest to the shoreline in the south of the site and may be able to connect to tidal channel in this configuration. The existing spit is narrowest at this location, indicating sediment accumulation rates are lower, so the channel may stay open for longer periods without maintenance. This configuration would place the channel farthest away from existing infrastructure, thus less impact to existing recreation at the site. There are some potential design constraints with this alternative, including the need for creating a sharp turn in the channel to avoid the roadway while connecting the channel to Puget Sound. Also, southerly facing channels allow for wood and other debris to enter estuary and accumulate as can be seen in reference sites (Figures 4 to 7).

Of the four alternatives developed, alternative 2C has the highest likelihood of maintaining a tidal channel opening through natural processes, but it requires a significant amount of construction of new infrastructure to minimize potential flooding.

Recommended Alternative

While alternative 2C provides the largest potential ecological benefit by developing a tidal marsh of approximately 8 acres, the cost of this option will be one of the highest (similar to Alternative 1). In addition, the moderate wind-wave climate at the site may still close off the tidal channel over time if it is not mechanically maintained through excavation. Therefore, the recommended alternative is 2B which provides connection between the existing perennial fresh water marsh, an acreage of salt water marsh similar to other barrier embayments in the Whidbey Basin and minimize the required changes to roads and flood protection within the park.

Table 2. Comparison of conceptual alternatives.

Concept	Advantage	Disadvantages
Alternative 1	1. Maximize marsh area 2. Grain size distribution to the north indicates lower energy regime, less annual transport 3. Boat launch acts as a groin and maintenance on ramp could support maintenance of spit seaward of channel/parking lot 4. Reduce natural wood accumulation 5. Disposal of material from boat ramp to the north, can this be controlled to augment a spit not in new channel 6. Access to channel for maintenance can be add-on for park doing maintenance at boat ramp 7. Flushing of marsh on east side of road	1. Turn around/parking will lose some space and need elevation 2. Road needs to be elevated and bridge added 3. Northerly channels have history of closing off over time in Whidbey Basin 4. May cause erosion at base of bluff undermining some trees and exposing more bluff
Alternative 2a	1. No changes to road or parking 2. May reduce transport reaching boat launch 3. Low lying marsh closest to shoreline to the south 4. Narrowest portion of spit indicates accumulation rates are lower 5. Channel away from major infrastructure, so room for natural channel adjustment 6. Less impact on parking/ turn around area 7. Might be able to connect perennial stream into south channel	1. Minimal tidal marsh would decrease tidal currents for flushing 2. Southerly facing channels allow for wood and other debris to enter 3. No benefit to marsh east of road
Alternative 2b	1. No changes to parking 2. May reduce transport reaching boat launch 3. Low lying marsh closest to shoreline to the south 4. Narrowest portion of spit indicates accumulation rates are lower 5. Channel away from major infrastructure, so room for natural channel adjustment 6. Less impact on parking/ turn around area 7. Might be able to connect perennial stream into south channel	1. Small tidal marsh would decrease tidal currents for flushing 2. Southerly facing channels allow for wood and other debris to enter estuary and accumulate 3. Road needs to be elevated to act as protective berm and bridge added

Alternative 2c	1. Maximize marsh area 2. May reduce transport reaching boat launch 3. Low lying marsh closest to shoreline to the south 4. Narrowest portion of spit indicates accumulation rates are lower 5. Channel away from major infrastructure, so room for natural channel adjustment 6. Less impact on parking/ turn around area 7. Might be able to connect perennial stream into south channel 8. Flushing of marsh on east side of road	1. Southerly facing channels allow for wood and other debris to enter estuary and accumulate 2. Road needs to be elevated and bridge added

Preliminary Design

Blue Coast worked with SRSC to develop a preliminary design including grading, precise calculation of marsh acreage, refinement of tidal channel configuration, and tidal channel dimensions. The acreage of new saltmarsh for the site was previously estimated as 4.4 acres, but after more detailed design was determined to be 3 acres. A preliminary design incorporated the design criteria listed below is shown in Figure 17.

Current velocity and discharge generated between the change in water levels from MLLW to MHHW through the tidal channels of six barrier embayment pocket estuaries in Puget Sound were measured during Phase 1 of the ESRP Tidal Channel Project (Côté et al 2018). The tidal channel maximum depth, maximum width, cross-sectional area and tidal volume for water levels between MLLW and MHHW were also measured or calculated as part of the study. The same parameters were calculated for the Camano Island site based on the preliminary design. In addition, learnings from the desktop analysis and review of barrier embayments were applied to this project.

The design criteria for Camano Island Tidal Marsh restoration are as follows:

1. The tidal channel should bisect the barrier beach perpendicular to the contours and then turn northwards on the west side of the park as opposed to due south as was originally shown in the design concepts.
2. The tidal channel should be fronted by a barrier spit that will grow in length to the north as it accumulates sediment on the south side of the spit. In addition, sites that have wind-wave exposure have been observed to have a second spit that turns inwards on the north side, which can be thought of as arms around the tidal channel protecting it from migration.
3. A lagoon of 3 acres is on the smaller end of the spectrum for barrier embayments/pocket estuaries and the regression analysis of intertidal area to cross-sectional area indicates the channel would need to be about 60 ft wide at MHHW. This is similar in size to Lone Tree Lagoon, a barrier embayment to the north of Camano Island.

3. The new barrier embayment would have approximately 1.5 feet of water in the estuary at MHHW. This water depth is used to calculate intertidal volume of water in the new embayment.
4. The bottom of the tidal channel at the location of hydraulic control is at an elevation that is 3 ft below MHHW, so the depth of water in the channel at MHHW would be 3 ft.
5. Tidal channels in barrier embayments are typically parabolic shaped as opposed to trapezoidal so the side slopes of the spits can be steep (1:4 to 1:5) and so the bottom of the channel will be 30 to 36 feet wide.
6. The tidal channel should have a slope similar to natural systems which is approximately 1%.
7. Protective berms or roadways should be an elevation of at least 13.6 ft MLLW (10-year extreme water level) to minimize the potential for flooding.

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CLOSURE

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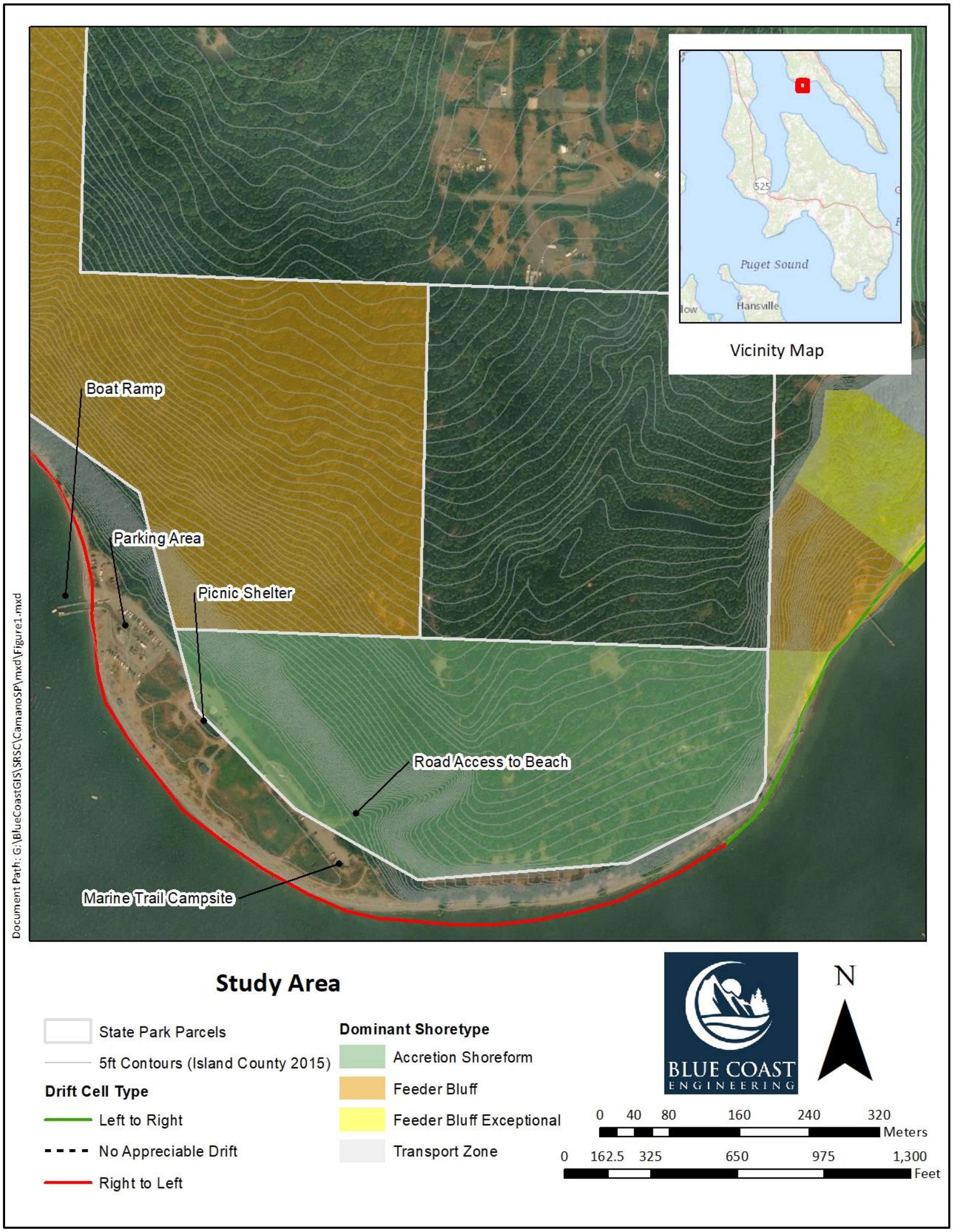


Figure 1. Local site geomorphology and topography.

Figure 2. Barrier beach shoreform at park (upper) and feeder bluffs to the east of the park (lower).

Figure 3. Photographs of grain size distribution to the north of the park boundary and adjacent to the southern park boundary.

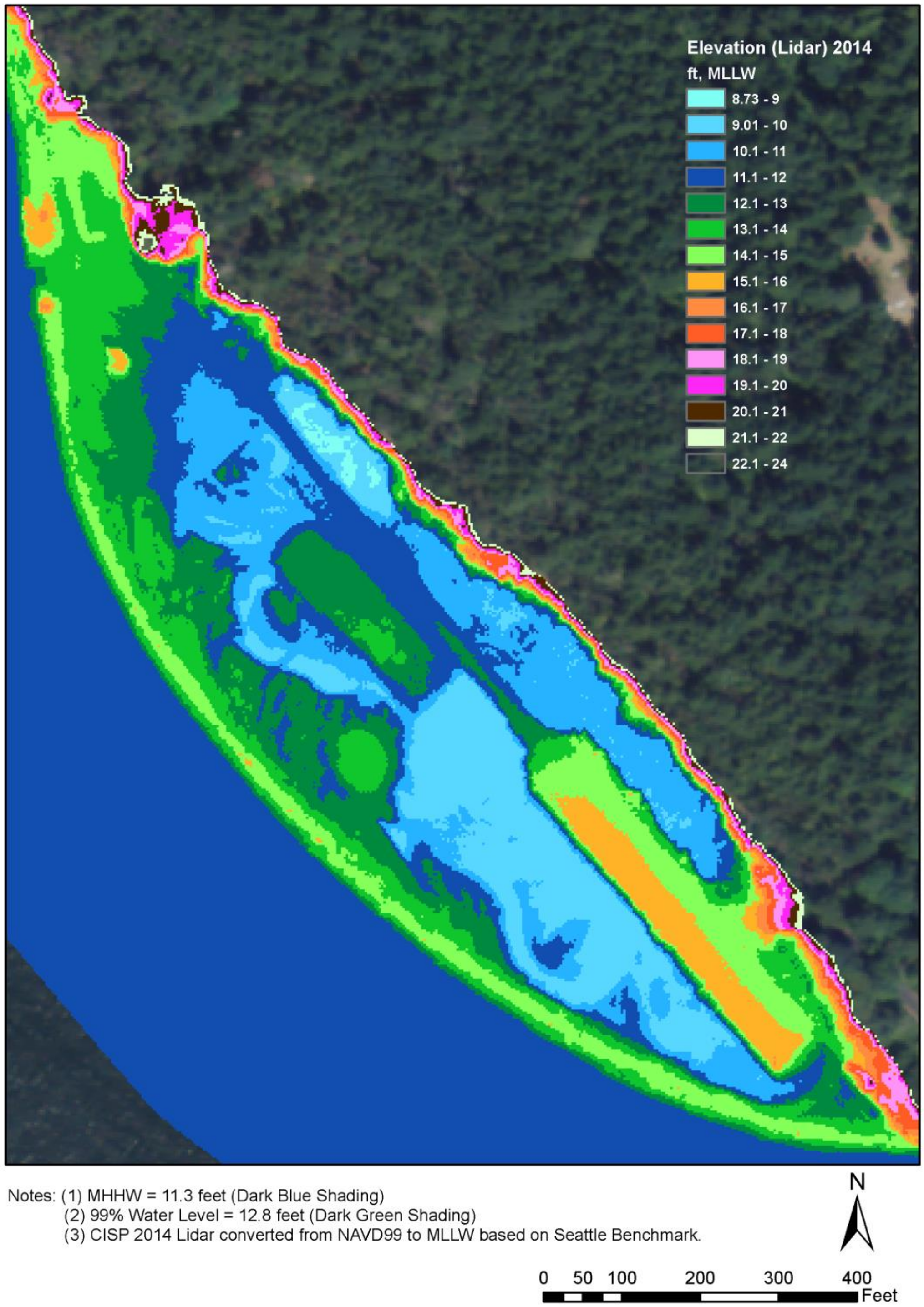


Figure 4. Elevation contours at project site based on 2014 LIDAR.

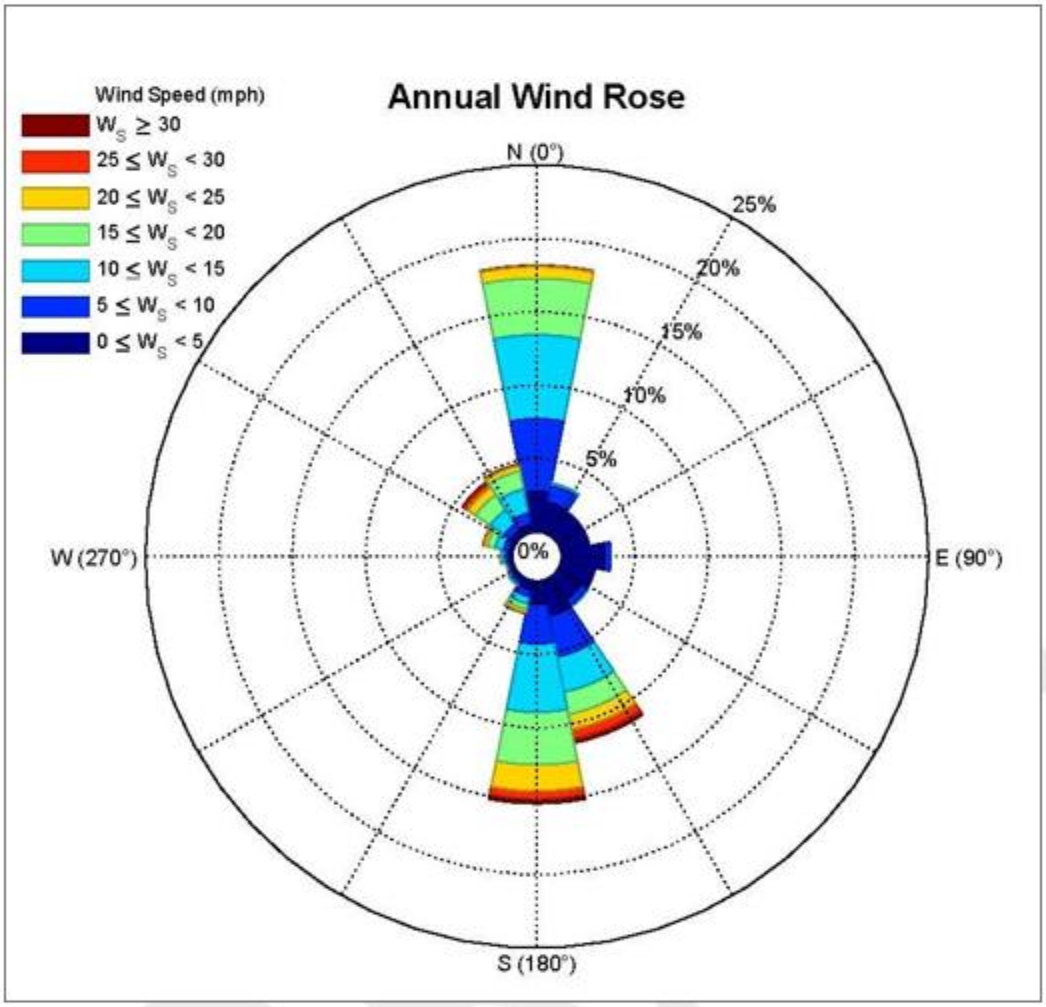
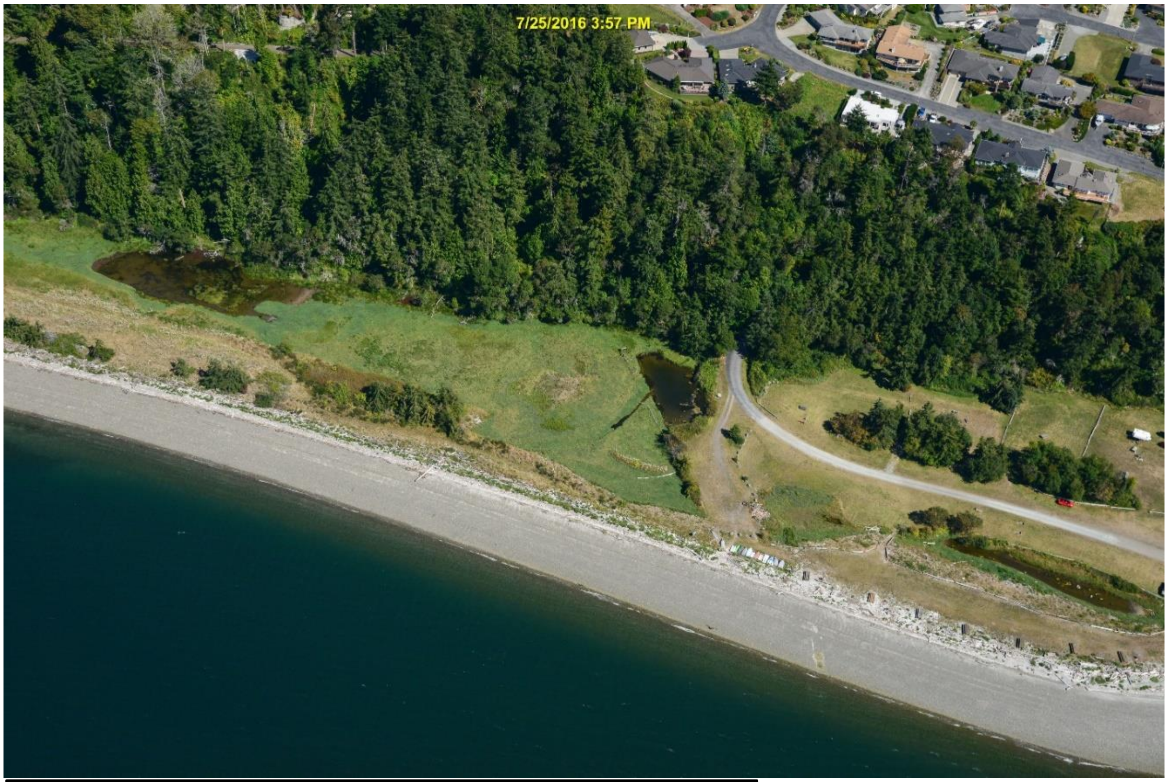


Figure 5. Wind rose diagram of wind speed and direction at Cama Beach State Park (adopted from ESA 2017).

Figure 6. Shoreline oblique aerial photo at KVI Beach, Vashon Island showing a reference site with a southerly flowing tidal channel (Ecology, 2017).



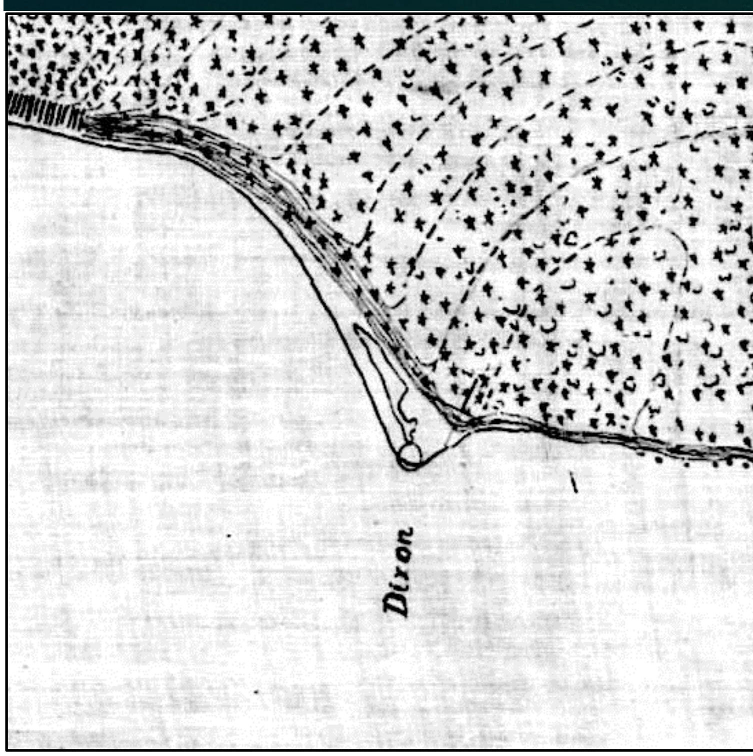


Figure 7. Shoreline oblique aerial photo at Onamak Beach, Camano Island (Ecology 2017) and T-sheet of Onamak Beach showing a historic barrier embayment with tidal channel to the south.

Figure 8. Shoreline oblique aerial photo at Devil's Head, Key Peninsula (Ecology, 2006).

Figure 9. Shoreline oblique aerial photo at Devil's Head, Key Peninsula showing the eroding bluffs to the east of the area (Ecology 2017).

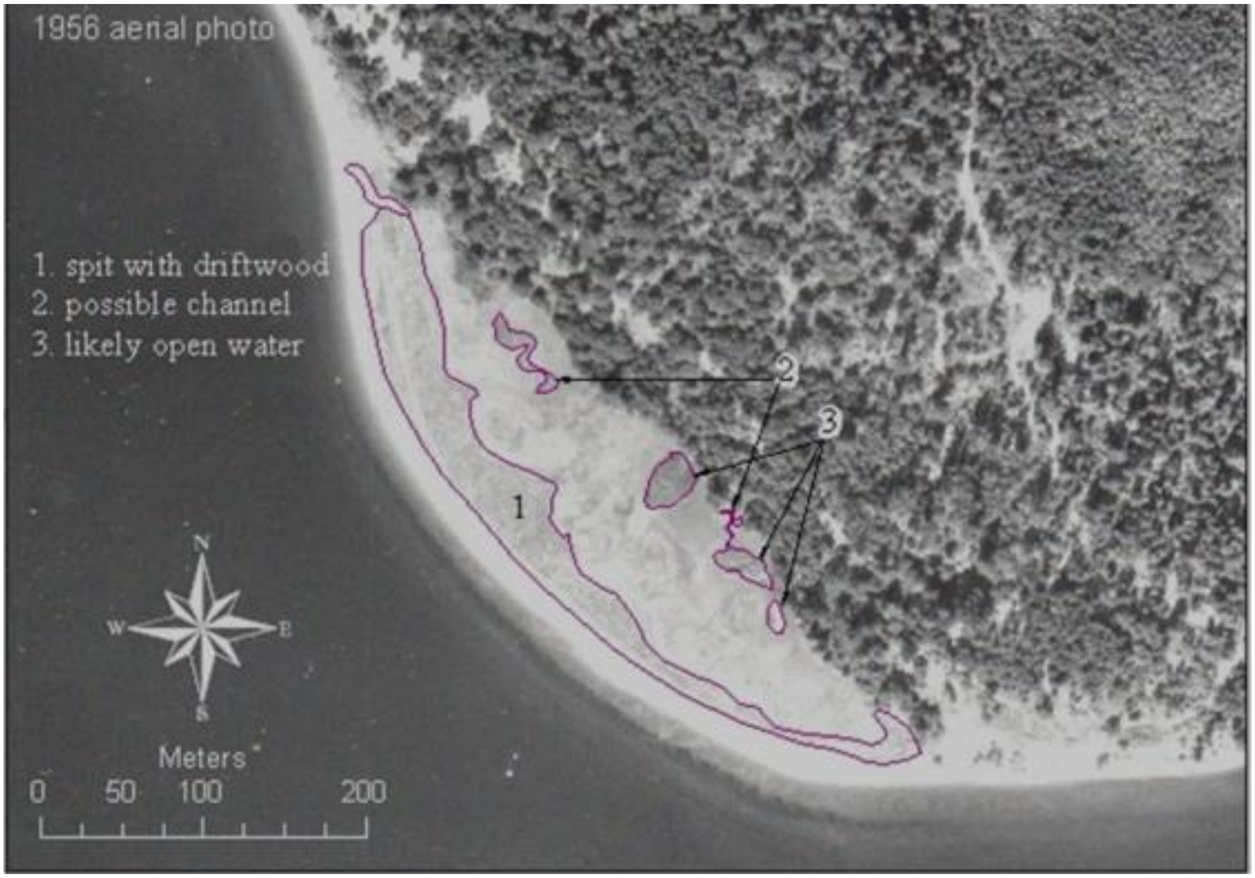


Figure 10. 1956 aerial photo of the project site.

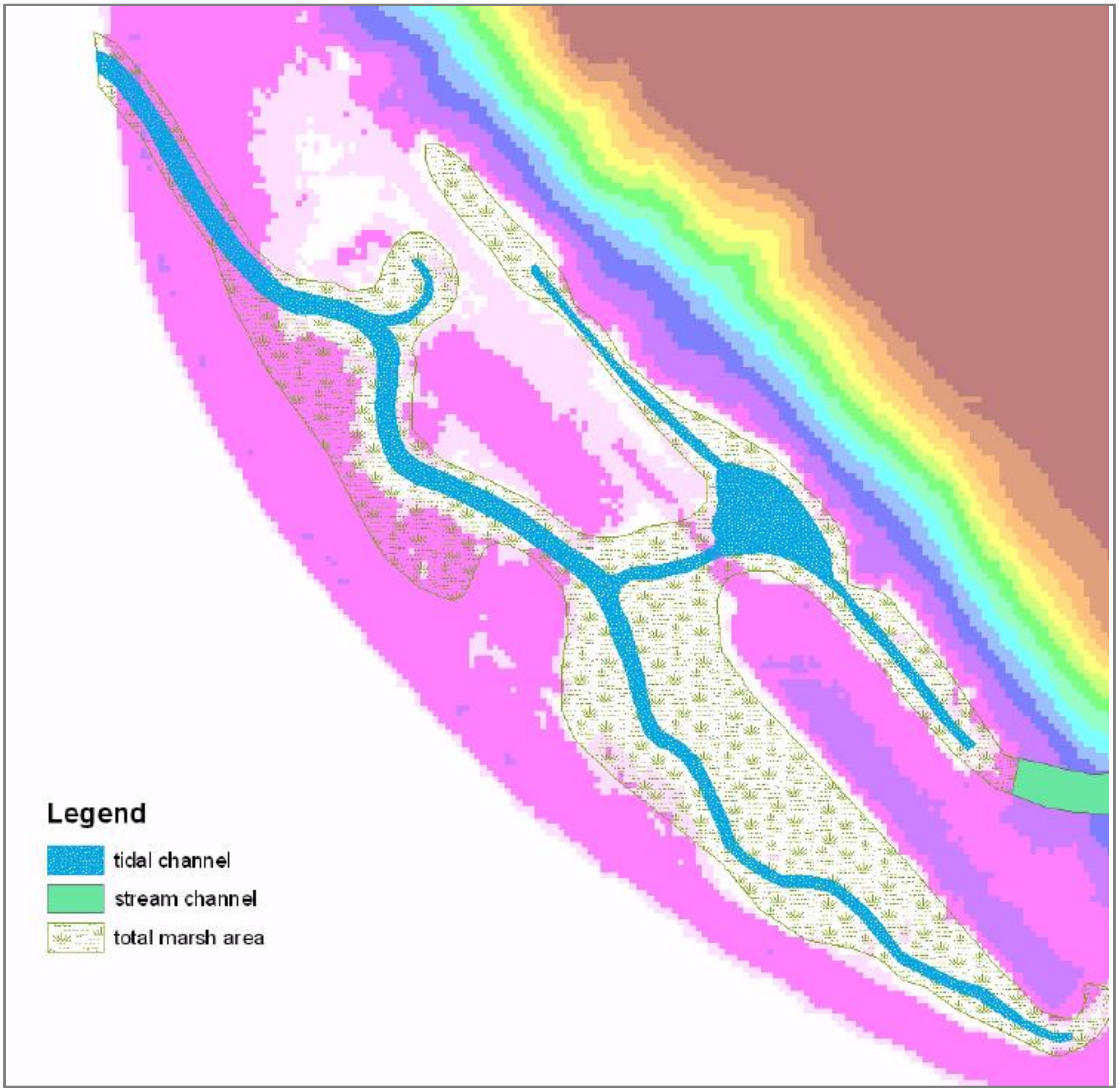


Figure 11. Original concept for marsh design.

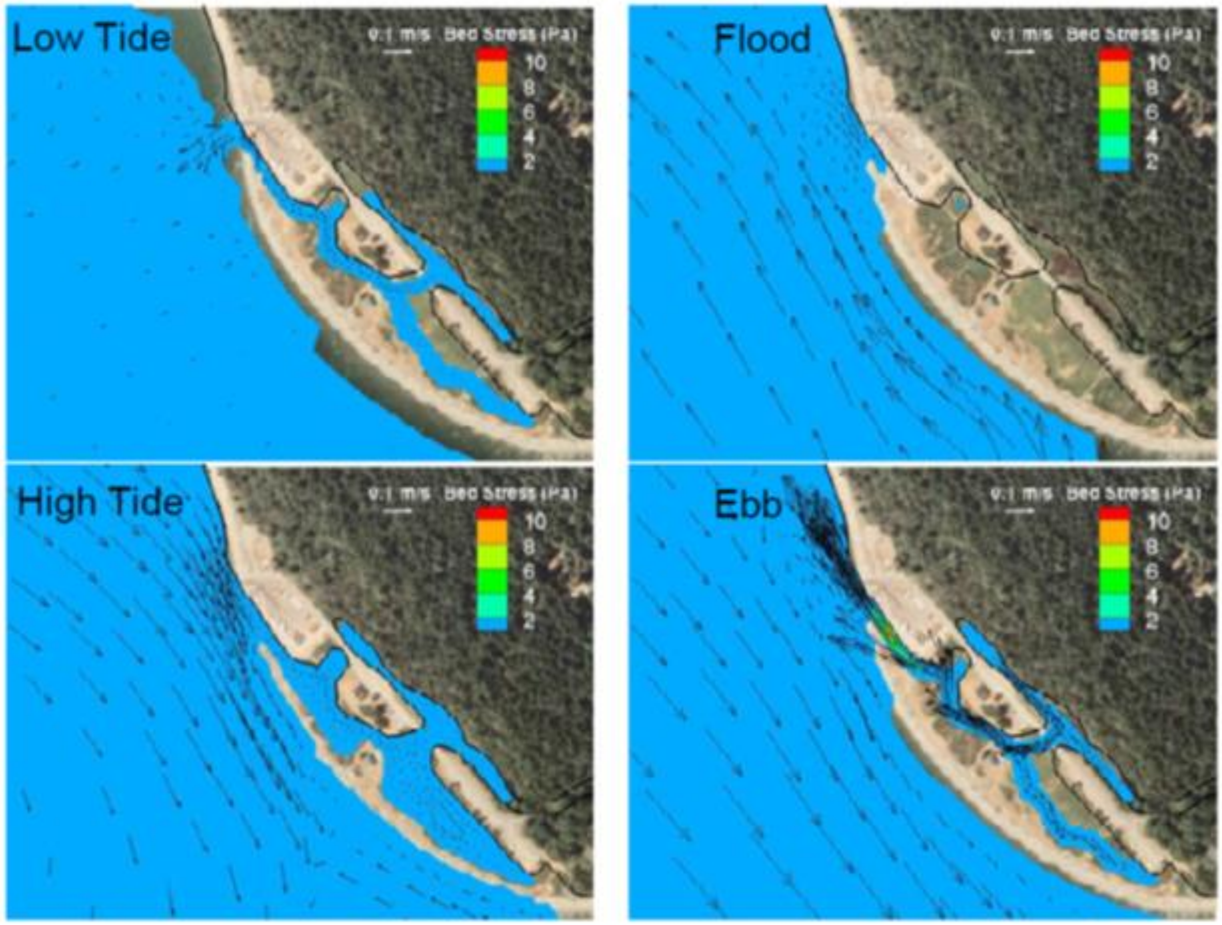


Figure 12. Tidal circulation modeling completed by Batelle for SRSC early feasibility study (adapted from McBride et al, 2010).

Notes:
1. CISP 2014 Lidar converted from NAVD88 to MLLW based on NOAA Seattle Tidal Benchmark (0' MLLW = -2.3' NAVD88)
2. Annual Highest Tide taken from NOAA Seattle Tide Station (1% exceedance water level).
3. Existing Picnic Shelter and Restroom Structure may need additional protective berms to reduce risk of flooding following any proposed restoration option. This will be determined as part of 30% design for the preferred alternative.

Figure 1: Alternative 1, North Tidal Channel

Figure 13. Conceptual design alternative 1 with tidal channel to the north at base of bluff.

Notes:
1. CISP 2014 Lidar converted from NAVD88 to MLLW based on NOAA Seattle Tidal Benchmark (0' MLLW = -2.3' NAVD88)
2. Annual Highest Tide taken from NOAA Seattle Tide Station (1% exceedance water level).
3. Existing Picnic Shelter and Restroom Structure may need additional protective berms to reduce risk of flooding following any proposed restoration option. This will be determined as part of 30% design for the preferred alternative.

Figure 2A: Alternative 2, SouthTidal Channel, Option A

Figure 14. Conceptual design alternative 2A with tidal channel to the south.

Figure 15. Conceptual design alternative 2B with tidal channel to the south.

Notes:
1. CISP 2014 Lidar converted from NAVD88 to MLLW based on NOAA Seattle Tidal Benchmark (0' MLLW = -2.3' NAVD88)
2. Annual Highest Tide taken from NOAA Seattle Tide Station (1% exceedance water level).
3. Existing Picnic Shelter and Restroom Structure may need additional protective berms to reduce risk of flooding following any proposed restoration option. This will be determined as part of 30% design for the preferred alternative.

0 50 100 200 300 400 Feet

Figure 2C: Alternative 2, SouthTidal Channel, Option C

Figure 16. Conceptual design alternative 2C with tidal channel to the south.

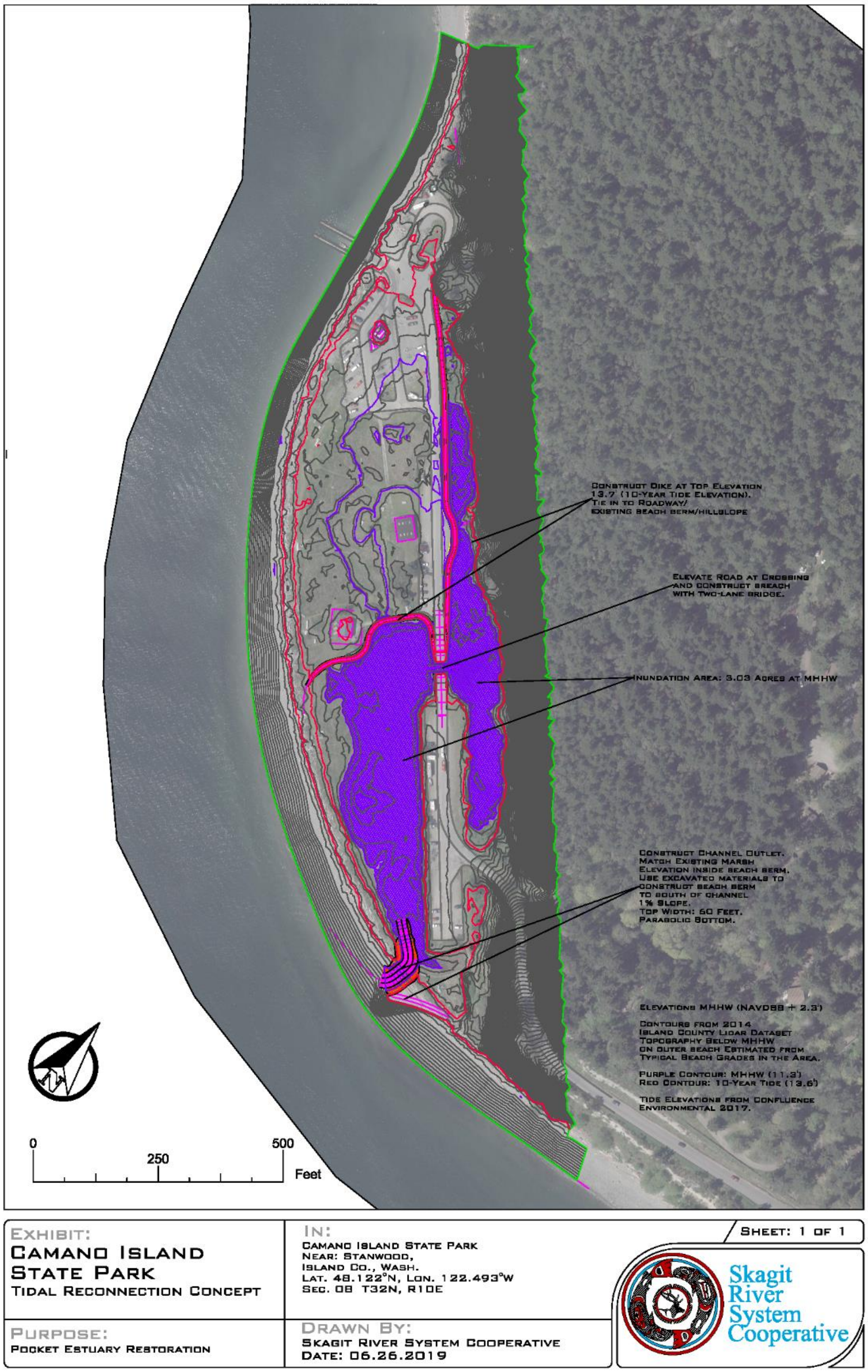


Figure 17. Preliminary design of preferred alternative with tidal channel to the south.